Deep Cores of Oahu, Hawaii and Their Bearing on the Geologic History of the Central Pacific Basin

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IN THE CENTRAL PACIFIC BASIN few studies of the earth's crust have been made, and those studies that have been undertaken have been mainly geophysical in nature: seismic, magnetic, heat flow, and gravity surveys. These geophysical data usually require for their correct interpretation some knowledge of the geologic properties of the crust, especially the upper crust; consequently, in order to supplement these geophysical data and for other more direct reasons, e.g., stratigraphic, palaeontologic, petrologic, etc., there has been for a long time a desire to take actual samples of the Central Pacific Basin crust. To realize this goal H. S. Ladd, J. I. Tracey, K. O. Emery, and others in the last twenty years have drilled several deep holes on Central Pacific islands. Unfortunately, the drilling techniques used did not allow the recovery of a core sample, so that actual lithologic sections of the upper crust were not obtained.

In October 1964 a grant was obtained from the National Science Foundation by the authors to drill a series of deep holes on the edge of the Ewa Coastal Plain, Oahu, Hawaii. The intent of this research program was to obtain complete sections of the upper crust utilizing a newly developed core barrel that allows nearly 100% core recovery. The Ewa Coastal Plain was chosen as the drilling site because it is the widest coastal plain in the Central Pacific Basin, thereby allowing the drilling to be done farther from the central island core than elsewhere in the Pacific.

The results obtained by drilling the first two holes were very rewarding. The first hole (Ewa No. 1) was drilled on the 158th meridian 200 yards inland from the beach (Fig. 2, inset). The basaltic core of Oahu was penetrated beneath 1,072 ft of interbedded coral reefs, lagoonal muds, sands, and soils. The second hole (Ewa No. 2) was drilled also on the 158th meridian about 2 miles inland from Ewa No. 1. In the second hole 517 ft of sedimentary rocks were penetrated before the basement basalts were encountered. More than 85% of the core was recovered in both holes, the first time in the Central Pacific Basin that such complete cores have been obtained from deep holes in the upper crust.

Not only are the recovered cores valuable in deducing the geologic history of the Central Pacific Basin but, because of their location on Oahu, they allow tectonic and eustatic deductions to be made concerning the submergence and emergence of the Hawaiian Archipelago. Furthermore, the Ewa holes are related to other deep drilling investigations in the Hawaiian area planned for the near future:

1. It is the desire of the authors to drill two more deep holes offshore along the 158th meridian to complete the stratigraphic section across the Ewa Coastal Plain. These offshore holes will be in water about 1,800 ft deep and will penetrate approximately 2,000 ft of crustal sediments.

2. Since the Oahu drilling was completed

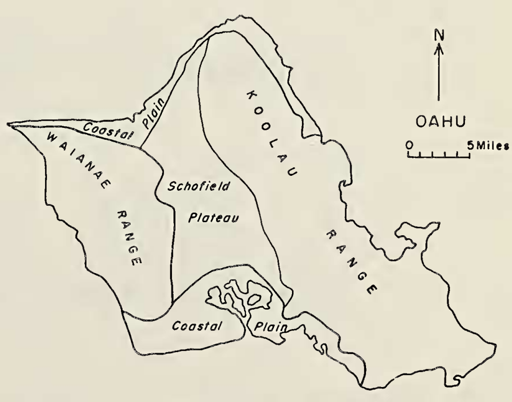

FIG. 1. Map of Oahu showing Ewa Coastal Plain on the south shore of the island.

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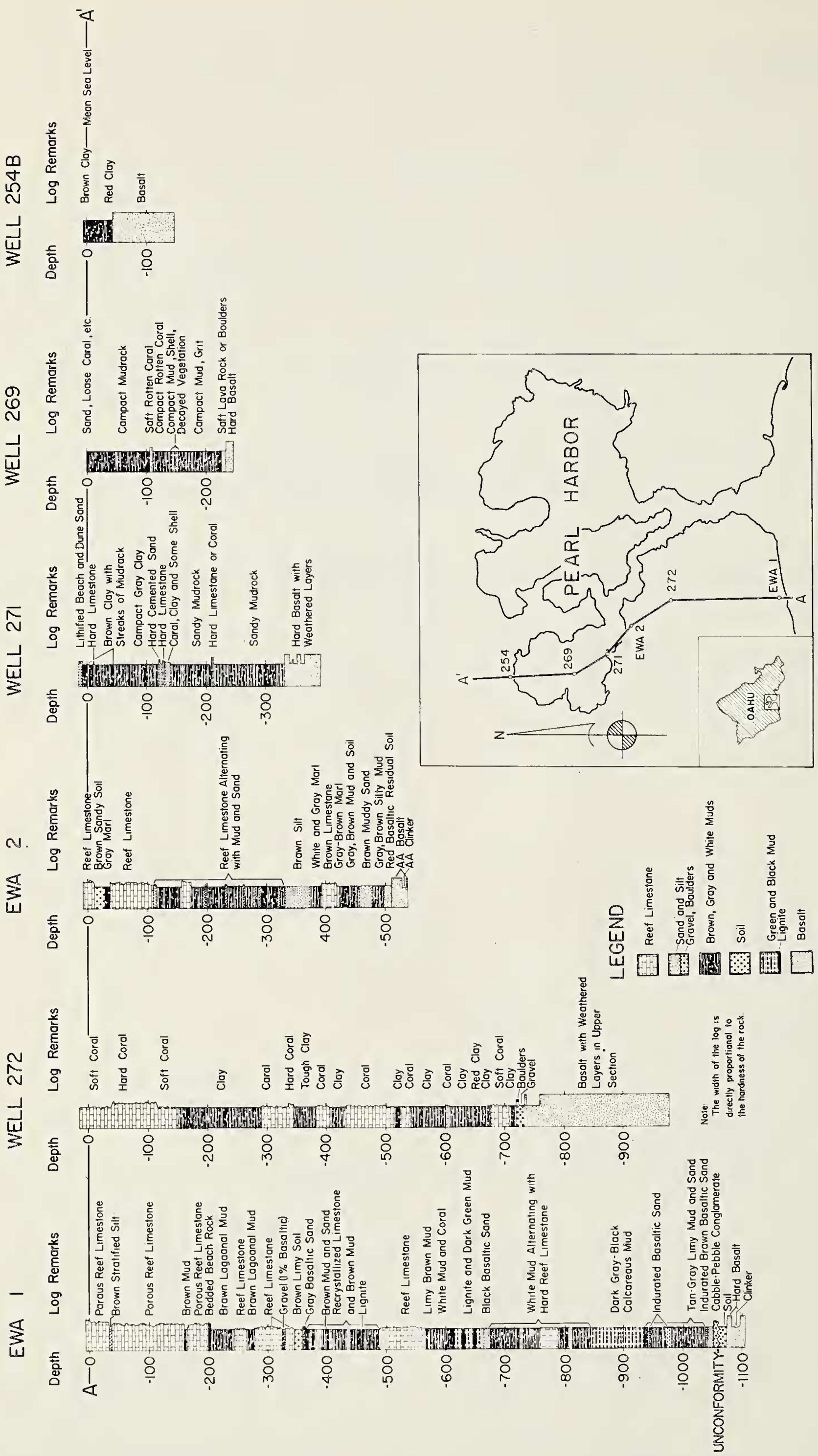

FIG. 2. North-south geologic section across Ewa Coastal Plain, Oahu.

two holes have been drilled into the basaltic basement of Midway Atoll. The same equipment used on the Oahu holes was used there. These holes penetrated deeply weathered basalt overlain by basaltic conglomerates, marine sediments, and coral reefs similar to those above the Oahu holes, indicating a long erosional and weathering period in the history of ancient Midway volcanoes prior to submergence (Stearns, 1966).

3. A proposal exists to drill a hole in the Kailua area of eastern Oahu to study the mantle-like material that appears to be close to the surface in that area. The hole will be drilled on land and probably will be over 6,000 ft deep.

All of the above studies are related in that geologic data in the form of complete lithologic sections of the crust are to be obtained by deep drilling. These data will allow a more complete understanding of the geologic history of the Central Pacific Basin and a more exact knowledge of the tectonic and eustatic history of the Hawaiian Archipelago.

The two holes (Ewa Nos. 1 and 2) recently

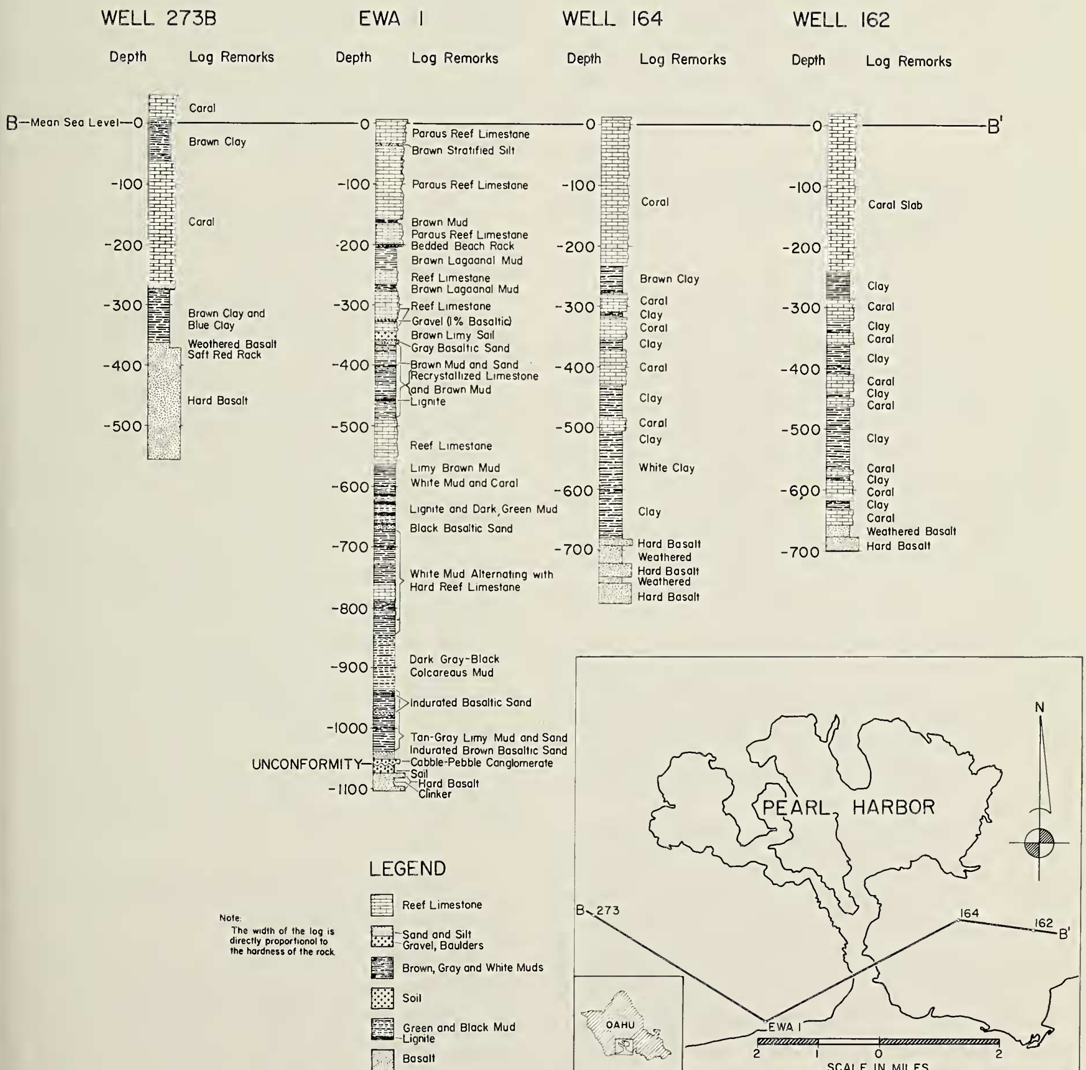

FIG. 3. East–west geologic section across Ewa Coastal Plain, Oahu.

drilled on the Ewa Coastal Plain are not the only holes that have been drilled on that plain. Hundreds of wells have been drilled from Barber's Point to Honolulu and from the mountains to the sea during the past 40 years (Stearns and Vaksvik, 1935, 1938). However, no samples were saved from these holes. Logs of these wells are frequently ambiguous as to terminology; "coral" and "limestone" are used interchangeably, and it is suspected that any white rock penetrated by the drill was logged as "coral."

Using recovered cores from Ewa Nos. 1 and 2, however, it has been possible to go back to these earlier logs and reinterpret them. In this manner a great deal of additional information was obtained that could be used to extrapolate the data from the Ewa holes (Figs. 2 and 3).

Mr. William Ebersole assisted in the project The holes were drilled by Layne International Company of Honolulu.

LITHOLOGIC TYPES

The sedimentary rock in the two Ewa cores consists mainly of various types of reef limestone alternating with shallow-water muds. A few soils, a layer of beach rock, two beds of lignite, basaltic sands, and stream conglomerates were encountered. The igneous rock recovered in the lower portion of each core consists of alternate flows of pahoehoe and aa basalt. Lithologic terms used throughout the following discussion are defined below:

Reef limestone. A sedimentary rock consisting of the remains of various corals, mainly *Porites,* calcareous algae, molluscs, etc., essentially in position of growth. Much of the original skeletal material has been replaced by secondary calcite and/or dolomite.

Mud. A marine or fresh water sediment consisting of particle diameters mainly in the silt and clay size range, i.e., 1/16 mm to about 1/1000 mm, and composed of various detrital minerals resulting from terrestrial weathering. Marine shells may be present. The various types of muds are described in terms of their colors; the muds in the Ewa cores owe their colors to the following constituents: (a) oxides of iron and aluminum (brown mud); (b) iron sulfides and organic detritus (black mud); (c) calcium carbonate particles mixed with brown or black mud (gray mud); (d) clay size particles of calcium carbonate presumably reef detritus (white mud); (e) clay minerals and ferrous iron (green mud).

Beach rock. A sedimentary rock consisting of calcareous beach sand cemented by calcium carbonate. Beach rock is commonly found forming within the beaches of tropical islands and owes its origin to the seepage of carbonate-rich ground waters through a beach composed of calcium carbonate particles. Beach rock is formed only at or within the tidal range and positively indicates a former shore line.

Reef breccia. A sedimentary rock composed of the angular fragments of an organic reef. The broken fragments may be ½–4 inches in diameter and are commonly mixed with sand and silt-size reef debris.

Lignite. Fossil plant remains altered by pressure to a highly friable, soft, black sedimentary rock. A low grade of coal.

Conglomerate. A sedimentary rock composed of rounded cobbles and pebbles intermixed with finer material.

Clinker. Rough, spinose, vesicular fragments of lava produced by lava flow.

Pahoehoe basalt. Lava with a smooth or ropy surface spread chiefly through tubes and characterized by round vesicles.

Aa basalt. A lava flow with a rough clinkery surface and base. Deflated and stretched vesicles characterize the solid part of the flow.

Marl. A calcareous clay.

Soil. The term is used in a general way to mean regolith on the basalt and any sediment altered by weathering.

Cobbles, pebbles, gravel, sand, silt, clay. The usage herein follows the usual dictionary definitions.

MEGASCOPIC DESCRIPTION OF CORES

Ewa No. 1 (Table 1)

The drilling site for this hole was located as far seaward on the Ewa Coastal Plain as it was feasible to drill, within 200 yards of the sea on the 158th meridian on the eastern end of the property of the U. S. Coast and Geodetic Station, 91-270 Fort Weaver Road, Ewa Beach, Oahu, opposite Ewa Beach Park. The terrace at this locality was a flat, low, emerged coral reef of undetermined age, partially covered with a thin discontinuous soil layer. The ground level is + 6.1 ft above mean sea level; all depths in the core are measured from ground level equaling zero.

Ewa No. 2 (Table 2)

The second hole on the Ewa Coastal Plain was also located on the 158th meridian but 2 miles inland from Ewa No. 1. The exact locality was within the confines of the West Loch of Pearl Harbor Naval Base, at a point a few hundred yards south of the West Loch shoreline. The ground level at the hole is 19.7 ft above mean sea level; all depths in the core are measured from ground level equaling zero.

PRELIMINARY SEISMIC DATA

On July 13 and 14, 1965 seismic refraction studies were made of the ocean bottom to the south of drilling site Ewa No. 1. The following results were obtained at a distance of 8.4 km seaward from the coast along the 158th meridian (21°15′N, 158°00′W): (1) water depth —0.36 km; (2) depth from sea surface to the upper surface of the basalt basement—1.1 km; (3) sound velocity in the sedimentary section = 2.8 km/second.

These data show the sedimentary column to be 2,920 ft in thickness at a distance of 4.6 miles offshore from Ewa No. 1 in a water depth of 1,182 ft. The sediment-basalt interface was found to be essentially parallel to the sea water-sediment interface.

PRELIMINARY GEOLOGIC HISTORY OF THE EWA COASTAL PLAIN

The following description applies to the outer edge of the Ewa Plain in the vicinity of Ewa No. 1:

1. Prolonged weathering and erosion of the upper surface of the Koolau basalts. Formation of thick soil deposits, deep incision of stream valleys, and deposition of stream cobbles, pebbles, and basaltic sand along the coast.
2. Gradual submergence.
3. Accumulation of thick deposits of shallow marine lagoonal sediments behind a barrier reef. Stream-transported muds and silts predominate, with occasional layers of basaltic sand and gravel. Inorganically precipitated $CaCO_3$ common to these sediments indicates a restricted oceanic circulation. Much of the mud is high in organic carbon, indicating swamp conditions. Typical lagoonal-deltaic sedimentary facies.
4. With continued submergence, the water deepened sufficiently to allow the lagoonal deposits to be superseded by calcareous muds and coral debris. These sediments indicate the barrier reef structure was in close proximity. The upper portion of this section grades into a hard reef limestone horizon at —786 ft MSL in the core.
5. Following the growth of these corals the progradation of the land was sufficient to shift the coral reef facies seaward, allowing at first the accumulation of gray calcareous mud and coral debris, and finally, the progradation of the land was sufficient to bring basaltic river sands and silts and dark-gray to black organic muds into the area. The environment again became swampy-lagoonal and eventually peat deposits accumulated, now represented by the lignite and soils found at —624 ft MSL. At this depth a major unconformity occurs which probably marks the Pleistocene-Pliocene boundary.
6. Following the deposition of the lignite beds the sea level rose, allowing the coral facies to shift landward. At first calcareous muds containing coral debris accumulated, but these were followed by the growth of marine coralline reefs more than 50 ft in thickness.
7. On top of this reef is found at first calcareous mud followed by brown mud and sands and soils, indicating a progradation of the lagoonal facies. At —406 ft MSL a minor unconformity occurs and continues upward through brown muds and basaltic sands and soils to a major unconformity at —358 ft MSL that most likely corresponds to the Kahipa-Mamala submarine shelf around Oahu (Stearns, 1966).
8. Subsequent to the development of this

TABLE 1

DESCRIPTION OF CORE FROM EWA NO. 1 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
0–2	Loose coral and sand	Hole started in exposed emerged coral reef.
2–41.8	Reef limestone	Coral in upright position of growth and reef debris.
41.8–43.8	Tuff (?)	Stratified fine grained material with thin horizontal calcite layers, possibly an altered tuff.
43.8–165	Reef limestone	Mostly *Porites* coral and nullipores. The corals are in upright position of growth. Starting at 96 ft the cavities in the reef limestone contain coatings of a red clay which X-ray and mineral analysis indicate is sediment derived from a basaltic terrane. The red mud becomes only a trace below 135 ft.
165–166	Brown mud with fragments of coral 1 inch across	
166–167	Brown compact mud	Brown mud full of fossil molluscs and fragments that represents a discontinuity.
167–203	Reef limestone	Hard white and cream colored reef with no soil in cavities.
203–209	Beach rock	Thin-bedded beach rock; contains about 10% basaltic grains, the rest Foraminifera, shell, and coral grains, very well rounded and cemented by calcite into hard limestone.
209–250	Brown mud	Brown mud containing 1–20% limestone grains.
250–270	Reef limestone	Hard fragmental reef with some brown mud in cavities. Much of it is recrystallized limestone.
270–283	Brown mud	Dark-brown organic mud mixed with coral fragments mostly 1 to 2 inches across.
283–290	Altered reef limestone	Soft, slightly muddy, powdery limestone; apparently altered top of reef containing thin limonite streaks.
290–311	Reef limestone	Fragmented limestone, mostly recrystallized and broken by drilling. Some heads of *Porites* and a few molluscs.
311–314	Muddy limestone	Recrystallized reef with 50% brown mud in interstices, mud content increasing downward.
314–315	Brown mud	About 90% brown mud and 10% limestone fragments.
315–331	Reef limestone	Muddy reef limestone, partly recrystallized.
331–333	Gravel (?)	Partly rounded reef limestone ½–1 inch across, mixed with similar size and shape basalt pebbles. Basaltic pebbles constitute 1% of deposit.
333–337	Reef limestone	Similar to 315–331 ft, with a few subrounded pebbles of basalt.
337–348	Reef limestone	Mud becomes whiter progressively with depth and decreases in quantity at 341 ft, where fragments increase in size.
348–350	Reef limestone	Same as above but white. Possibly the white mud is due to grinding action of bit.
350–355	Reef limestone	Brown mud filling interstices in a reef. Bit breaks it all up and makes a fragmental deposit with brown coating. Similar to 315–331 ft.
355–358	Limey mud breccia	White and brown mud with mostly small limestone fragments less than 1 inch across, a few 1½ inches across.

TABLE 1 (*Continued*)

DESCRIPTION OF CORE FROM EWA NO. 1 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
358–363	Brown mud	Pure dark-brown mud with irregular tubular cavities ½ mm across lined with limonite. No bedding visible. Last 6 inches is light brown.
363–364	Gray sand	Gray-brown fine sand; over 50% basaltic grains eroded from a basaltic terrane or water-laid lithic tuff deposit. No glass particles obvious.
364–371	Calcareous mud	Calcareous mud with limonitic streaks.
371–376	Reef limestone	Muddy fragmental reef limestone, much altered.
376–383	Calcareous mud	White calcareous mud.
383–394	Reef limestone	Muddy fragmental reef limestone probably broken by bit.
394–401	Mud and coral fragments	Layers of mud and mixed mud and coral fragments.
401–412	Brown mud	Brown mud with scarce limy grains. A 4-inch layer of fine weathered basaltic sand from 403.5 to 404 ft.
412–415	Reef limestone	Muddy reef limestone, with about 1 ft of altered limestone at top with laminations.
415–435	White limy mud	White chalky mud with a few hard chunks. Contains minute borings of marine organisms. Probably a chemical precipitate. Lumps of hard limestone at 424 ft and from 426–435 ft. Some are altered coral fragments.
435–444	Reef limestone	Recrystallized reef limestone and white mud. Transition into material above. Mostly fragments broken up by drilling(?). At 440 ft mud becomes browner and at 444 ft becomes predominant over coral.
444–453	Brown mud and limestone fragments	Mud and coral reef limestone fragments.
453–464	Gray mud	Same as above but fewer rock fragments. Possibility that some rock fragments are chiefly crystallized calcite in place.
464–464.5	Organic mud	Brown layer with 1-inch layer of black lignite at bottom.
464.5–472	Gray mud	Gray lagoonal mud; in places 4 inches of it is hard cemented mud-limestone. Contains one oyster shell and a few other types of molluscs.
472–493	White mud	White calcareous mud with hard crystalline calcite lumps toward the bottom. Spherical and oval grains suggest altered Foraminifera.
493–497	Reef breccia (?)	Fragmental limestone containing large oyster shells and other molluscs. The mud matrix is darker than above. The whole deposit resembles a fine-grained reef talus deposit.
497–572	Reef limestone	Fragments of reef limestone ¼–3 inches across, probably broken by bit; probably highly permeable structure. Oyster shell at 523 ft. Mostly recrystallized. At 535–540 ft several zones of smaller sized fragments and white mud. Oyster at 546 ft. *Porites* at 545 ft. At 545–555 ft much recognizable coral, less altered than above.

TABLE 1 (*Continued*)

DESCRIPTION OF CORE FROM EWA NO. 1 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
572–575	Brown mud and lime	A brown mud full of streaks and nodules of lime and a few shells. At 575 ft a hard 1-inch layer of dark greenish claystone full of shells in excellent state of preservation.
575–585	White mud and lime	White calcareous mud full of nodules becoming indurated at 579–580 ft, then calcareous mud again.
585–590	Reef limestone	Highly altered fragmental reef.
590–597	White limy mud	White calcareous mud with nodules scattered throughout.
597–609	Greenish mud	Greenish calcareous mud, highly fossiliferous, containing irregular red iron oxide streaks.
609–617	White mud	At 611 ft in the white mud is a 1-inch layer of fine grained tuff. A few chunks of very hard chemically precipitated limestone.
617–629	Green and black mud	Greenish calcareous mud, highly fossiliferous to 623 ft, then organic mud becoming blacker with depth.
629–631	Lignite	Firm lignite full of fossil plant remains; no shells.
631–635	Gray-green mud	Calcareous organic mud full of shells.
635–646	Gray mud	Gray mud with shells.
646–660	Dark-gray mud	Mud is becoming more organic; still highly fossiliferous.
660–668	Green and black mud	Greenish-brown to olive black mud. Recognizable weathered basaltic grains. Few fossils.
668–675.8	Black sand	Thin-bedded, compact, fine basaltic sand and silt.
675.8–676.5	Fine sand	Fine calcareous sand and silt, highly fossiliferous.
676.5–686	Gray mud	Gray calcareous mud with two beds of black mud at 678 and 678.5 ft. Shells are in thin zones.
686–706	Tan mud	Tan mud full of fossils. A layer of calcareous sand with abundant rounded grains of basalt and one unweathered feldspar crystal possibly indicating tuff source at 692–693 ft. Laminated at 699 ft.
706–727	White mud	Chalky white mud; fossils scarce.
727–727.4	Brown mud	Firm brown mud.
727.4–728	Gray mud	Calcareous gray mud.
728–735.5	Reef limestone	Hard reef limestone; some layers contain grains of lime.
735.5–764	White mud and limestone nodules	Hard limestone fragments in white mud, possibly a breccia transitional to reef below.
764–792	Reef limestone	Highly altered fragmental reef limestone with a few shell molds and pockets of clay. White mud layer at 776–778 ft.
792–811	Gray mud	Gray calcareous mud, some limy streaks, and scarce solid nodules and concretions.
811–816	Reef limestone	Reef limestone.
816–851	Gray mud	Gray calcareous mud with hard nodules and concretions up to 3/8 inch across. Some indurated layers. At 846–851 ft some mixed gray and green mud.

TABLE 1 (*Continued*)

DESCRIPTION OF CORE FROM EWA NO. 1 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
851–858	Olive black mud	Highly fossiliferous mud with sharp basal contact.
858–931	Gray and black mud	Gray calcareous mud with no nodules and some shells. At 874 ft a ½-inch layer of basaltic sand with some layers of gray-black and black mud, highly fossiliferous and full of basaltic grains and microscopic fossils. Some silt layers at 911–921 ft.
931–942	Olive black mud	Similar to above, poor in fossils, but uniformly dark.
942–948	Gray mud	Similar to above except for color.
948–950	Basaltic sand	Indurated basaltic sand and clay; basalt grains diverse and weathered.
950–966	Gray mud	Indurated gray calcareous mud. No fossils observed.
966–979	Brown mud	Indurated brownish-black mud.
979–930.5	Brown sand	Indurated fine basaltic sand and silt.
980.5–981.5	Brown clay	Indurated brown silty clay.
981.5–984	Brown sand and gravel	Indurated brown basaltic sand with scarce pebbles up to ½ inch across.
984–991	Brown mud	Indurated brown fossiliferous silty clay containing a 1-inch piece of *Porites* coral embedded in clay at 988 and 990 ft.
991–1015	Gray mud	Indurated gray mud with limy zones and nodules. Oyster at 1,004 ft and more at 1,009 ft. Another oyster at 1,015 ft.
1015–1043	Tan and gray mud	Hard very indurated brown mud, in places fossiliferous. Oyster shell, other fossils at 1,025 ft.
1043–1054	Brown sand	Typical brown basaltic indurated sand; grains mostly weathered limonite stained areas.
1054–1061.5	Conglomerate	Cobbles and pebbles up to 6 inches across, mostly dense blue basalt with a layer of silty clay, sand, and small pebbles at 1,055.5–1,057 ft. The sandy layers may be the matrix washed by drilling. Sand again at 1,061–1,061.5 ft.
1061.5–1072	Brown clay	Well indurated brown silty clay. No fossils noted. Basaltic grains visible. Becomes sandy at 1,071 ft for 1 ft.
1072–1077.5	Weathered basalt	Weathered basaltic aa clinker typical of a subsoil, consisting of partly decomposed clinker in a softer matrix, with creamy montmorillonite in the interstices. The top soil has been eroded away by the stream which emplaced the basal conglomerate.
1077.5–1088.3	Basalt	Solid basalt with large stretched vesicles typical of an aa lava. One unbroken core is 31½ inches long. The rock is nonporphyritic.
1088.3–1089	Basaltic clinker	Partly weathered red clinker.
1089–1097	Basaltic clinker	Red aa clinker.
1097–1107	Pahoehoe	Very vesicular olivine pahoehoe with slightly weathered surface.

TABLE 2

DESCRIPTION OF CORE FROM EWA NO. 2 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
0–10	Artificial fill	Crushed blue basalt and coral fill for drill platform.
10–18.8	Calcareous soil	Tan calcareous muddy soil with secondary calcified lumps.
18.8–36.5	Brown sandy soil	Chiefly basaltic grains; a few pebbles of basalt ¼ inch across. Some secondary calcite nodules. Changes to plastic brown clay downward.
36.5–46	Gray marl	Lumps of lime and concretions in gray mud; probably weathered surface of underlying reef.
46–102	Reef limestone	Hard reef limestone with shell molds, much recrystallized.
102–118	Reef detritus	Reef limestone with red mud in the interstices to 111 ft, and then changes to gray mud.
118–120	Brown sand	Fine silt and sand becoming coarser toward the bottom. Sand contains 50% well-rounded basaltic grains.
120–122	Coarse calcareous sand and gravel	Subangular reef detritus.
122–129	Brown mud	Fine mud. No lime present.
129–141	Indurated limy mud	Grayish-brown indurated mud with sharp break at top. Suggests very different environment. Contains tiny holes, possibly root holes with limonitic stain. Silty at 137–139 ft, with concretions. Some holes are lined with concentric structure.
141–161	Brown mud	Brown mud with mottled soil structure.
161–162	Brown silt and sand	Brown basaltic sand.
162–163	Brown mud	
163–165	White mud	White calcareous mud with some calcareous fragments; much recrystallized calcite with ⅛-inch crystals.
165–182	Reef limestone	Recrystallized reef limestone in fragments.
182–184	Limestone fragments in brown mud	Broken reef fragments in mud.
184–184.2	Black organic mud	
184.2–192	Brown mud	
192–194	Fine sand	Basaltic fine sand.
194–199	Brown mud	
199–204	Muddy fine sand	
204–208	Gravel and sand	Basaltic pebbles partly weathered in a sandy matrix.
208–239	Brown mud	Brown mud with pure calcite lumps ½ inch across.
239–241	Gravel and sand	Brown dirty basaltic sand with tiny round pebbles up to ¼ inch across.
241–262.5	Brown mud	
262.5–263	Sand and gravel	Brown nearly completely weathered basaltic gravel (¼ inch or less) and sand.
263–268	Brown mud	
268–271	Coarse sand	Coarse sand (basaltic) and mud.
271–274	Brown mud	Brown basaltic mud.
274–286	Brown and white mud	Brown mud with soft secondary lime deposits and irregular masses. A few hard calcite lumps. Lumps become more numerous at 285 ft.
286–288	Brown mud	
288–290	Fine sand	Fine basaltic sand and mud. Sand grains are mostly decomposed and have a variety of colors.

TABLE 2 (*Continued*)

DESCRIPTION OF CORE FROM EWA NO. 2 HOLE

DEPTH (IN FEET)	ROCK TYPE	DESCRIPTIVE NOTES
290–294	Brown mud	Brown basaltic mud.
294–297	Fine Sand	Brown basaltic sand and mud.
297–300	Brown mud	Brown basaltic mud.
300–301	Brown sand	Brown basaltic sand showing ⅛-inch and ¼-inch layers of coarse and fine sand.
301–307	Brown mud	Brown basaltic mud.
307–310	Fine sand	Brown basaltic sand and mud.
310–326	Brown mud	Brown basaltic mud, very mottled starting at 328 ft. Much limonitic from 333 to 334 ft along fractures.
326–330	Brown sand	Basaltic sand and silt much weathered.
330–339	Brown mud	Brown laminated mud.
339–344	Brown sand	Brown calcareous (secondary) sand, in places indurated with lime.
344–381	Brown silt and mud	Brown silt with soil structures in places.
381–400	White and gray marl	Mottled gray, white, and brown mud. Contains oyster shells and lime nodules.
400–415	Brown limestone	Recrystallized reef. At 405 ft 3 inches of brown mud mixed with coral fragments.
415–418	Brown marl and limestone	Fragments of recrystallized reef mixed with brown mud.
418–420	Brown and gray marl	Fragments of limestone mixed with brown and gray clay.
420–425	Gray limestone	Large fragments of limestone, probably recrystallized reef, oyster shells, etc., mixed with some gray and brown mud between 420 and 423 ft. At 423–425 ft large sections of limestone.
425–428	Gray-brown marl	
428–438	Brown mud (soil)	Plastic brown silty clay.
438–447	Gray marl	At 443 ft a 4-inch layer of red soil.
447–462	Brown mud (soil)	Stratified; soil structure contains well weathered basalt pebbles.
462–486	Brown muddy sand	At 467–469 ft and at other depths nearly pure coarse medium basaltic sand; remainder of section muddy sand; at 483–486 ft no sand, just brown mud.
486–499	Brown gray marl	Oyster shells abundant. The core from 487 to 498 ft was lost in a drilling mishap, but the cores at 487 and 498 ft were of the same lithology, and so possibly the missing 11 ft are also brown gray marl.
499–504	Brown silty mud	
504–517	Red basaltic, residual soil	Numerous highly weathered basalt cobbles; e.g., at 508, 510, 511, 512 ft, all about 4–6 inches. At 513 to 514.5 ft one large pahoehoe boulder 1½ ft in diameter was cored. From about 515 ft the soil grades imperceptibly into soft weathered aa basalt.
517–535	aa basalt	At 517 ft rotten aa basalt; no distinct upper surface; grades continually into soil above. From about 518 ft blue weathered aa basalt; large elongated vesicles.
535–542	aa clinker (soil)?	Weathered aa clinker, lower portion highly weathered into soil structures.
542–544	aa basalt	Blue, fractured, somewhat weathered aa basalt.

surface, the coral reef facies shifted landward, allowing the accumulation of a thick coralline limestone reef.

9. The growth of this reef was followed by a progradation of the lagoonal facies during which time nearly 100 ft of brown lagoonal mud accumulated. The upper surface of this mud is capped by several feet of bedded beach rock, indicating a still stand at —203 ft MSL.

10. Above the beach rock is another reef limestone section indicating a migration of coral facies landward again. After a short time this trend reversed itself, for at —160 ft MSL brown mud and soil occur, indicating a progradation of the lagoonal facies. Both of the above two unconformities may correspond with the Penguin Bank stand of the sea.

11. Above this level the coral reef facies advanced inland and dominated the remaining portion of the core except for one soil horizon at —38 ft MSL that may correspond to the Waipio stand of the sea.

12. The reef making up the present surface of the Ewa Plain appears to belong to the Waimanalo + 25-ft stand of the sea, inasmuch as reef limestone can be traced from Ewa No. 1 to Ewa No. 2 where it overlies lagoonal muds. The surface of this reef probably has been eroded by the sea as it retreated from the + 25-ft level to the last glacial low stand.

CURRENT RESEARCH AND FUTURE PLANS

It will be several years before the Ewa cores have been thoroughly examined. Even then the cores will continue to be used for comparison with cores obtained elsewhere. The interpretation of results of the preliminary core examination, especially of those sections dealing with the geologic history, doubtless will be modified as the research proceeds. The cores are stored at the Hawaii Institute of Geophysics, University of Hawaii, Honolulu.

The present plans for the examination of the Ewa cores include palaeontologic, mineralogic, and chemical analyses of selected samples along the core. Specifically the following types of studies are currently underway:

1. Soil analyses. Chemical and mineralogic studies of samples from suspected soil horizons; climatic and other environmental interpretations of proven soils.

2. Geochemical analyses. Absolute dating of various horizons within the cores by means of radioactive decay of certain elements. Methods used will include K-Ar, C^{14}, and a new helium method. Paleo-temperature measurements will also be made.

3. Palaeontologic analyses. Macro- and micropalaeontologic studies of fauna and flora; determinations of geologic age by the use of these fauna and flora; paleoecologic studies.

4. Sedimentologic analyses. Textural studies of the sediments and sedimentary rock; studies of the sedimentary environments.

5. Mineralogic and petrologic analyses. Optical, chemical, and X-ray determinations of minerals and rocks, including analyses of the underlying basalts.

The results of these analyses will give a partial answer to such questions as the tectonic history of the Hawaiian Archipelago and the nature and magnitude of the eustatic changes in sea level recorded in the Ewa cores. However, additional information will be necessary before the complete stratigraphic and paleoecologic history can be unravelled. Most of the sediments in the Ewa cores indicate either a lagoonal or back reef environment. A very extensive barrier reef undoubtedly lay to seaward of the present Ewa sites throughout most of the geologic period recorded in the cores. Without cores through this reef the stratigraphic interpretation of the present Ewa cores is handicapped. Consequently, plans are underway for a research program to drill two more holes in the Ewa area, both offshore and in the area of the anticipated barrier reef. The first hole would be drilled in about 400 ft of water three miles off the beach along the 158th meridian. This deeper hole would be drilled over the 1,800-ft shelf, possibly Miocene in age (Menard et al., 1962). Sediment thickness in this area is about 2,000 ft, based on seismic work.

With the complete cores recovered from these two offshore holes it would be possible to trace completely the sedimentary facies changes from terrestrial to lagoonal to barrier reef both horizontally and vertically throughout the Pleistocene Epoch and possibly the later Tertiary Period.

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